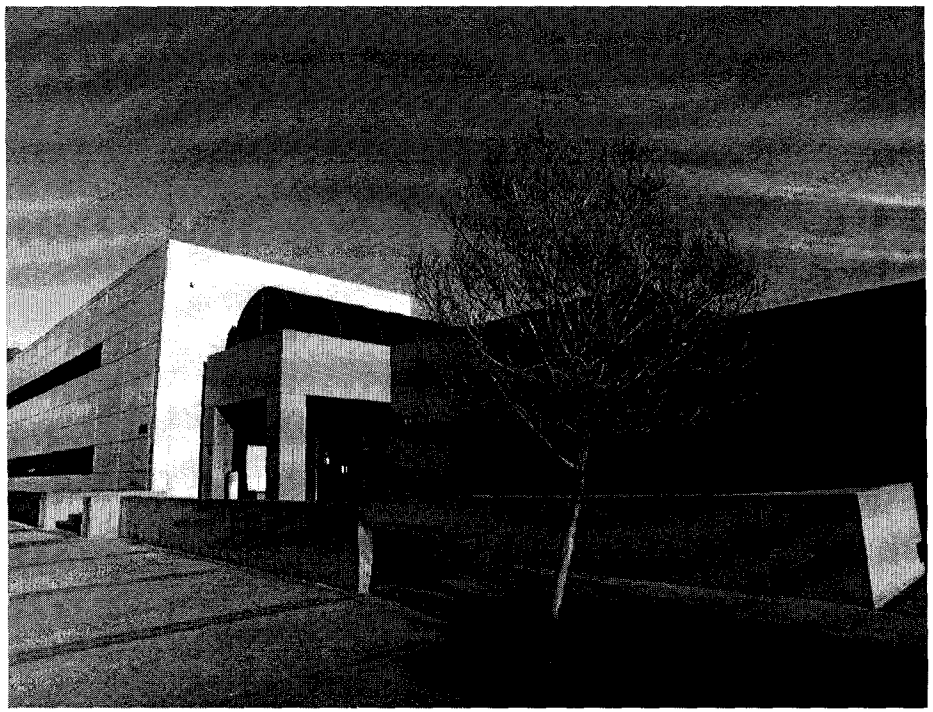
NASA / JPL Institutional Facility

Microdevices Laboratory (MDL)



James L. Lamb
Manager, Microdevices Laboratory

MICRODEVICES LABORATORY (MDL) OVERVIEW

- MDL Description
- Processing Service Support Description
- Capabilities
- Technology Development Areas
- Accomplishment Metrics
- Past Examples of Services Provided
- Summary

Microdevices Laboratory (MDL)

DESCRIPTION

- **A STATE-OF-THE-ART DEVICE PROCESSING FACILITY OFFERING END-TO-END DEVICE DEVELOPMENT FABRICATION AND CHARACTERIZATION CAPABILITES FOR SEMICONDUCTOR (Si, GaAs, & InP) AND SUPERCONDUCTOR DEVICE DEVELOPMENT.**

- **FACILITY IS FOCUSED ON CREATING AND DEVELOPING NEW SENSORS AND MICRODEVICES FOR SPACE APPLICATIONS -- BUILDING BLOCKS ENABLING NASA'S VISION OF SMALLER, FASTER, BETTER, CHEAPER SPACECRAFT**

- **AN INSTITUTIONAL FACILITY MANAGED BY JPL'S SPACE MICROSENSORS TECHNOLOGY SECTION (384).**

- **SUPPORTS R&D AND DELIVERIES TO MEET SPECIALIZED NASA/JPL NEEDS:**
- **DIRECT USE POSSIBLE:**
  - **MULTI-USER JPL LABORATORY WITH PROCESSING FACILITES OPEN TO ALL JPL PERSONNEL, AS WELL AS CALTECH, UNIVERSITIES, INDUSTRY, OTHER GOVERNMENT AGENCIES, OTHER NASA CENTERS, ETC.** (PRIORITIZED TO ENSURE FLIGHT NEEDS ARE MET)
- **INDIRECT USE ALSO AVAILABLE:**
  - **SPECIALIZED SEMICONDUCTOR PROCESSING SERVICE SUPPORT IS AVAILABLE**

Provide Microdevices Laboratory Services Process

Provide Analytical Laboratory and Testing Services Subdomain
Provide Enabling Services Domain

Process Owner : James L. Lamb

Specialized semiconductor processing service support is available through the Provide MDL Services Process utilizing JPL's Microdevices Laboratory (MDL)

JPL's Microdevices Laboratory (MDL) is an institutional facility managed by the Space Microsensors Technology Section (384). MDL is chartered to create, develop, integrate, and deliver novel microdevices and critical microdevice technologies enabling innovative NASA and DoD Space Missions and enhancing U.S. competitiveness worldwide. (MDL makes sensors and microdevices for space applications in a variety of technology development areas.)

MDL Services provides support to JPL and Caltech personnel (including industrial partners through membership in the Technology Affiliates Program), other government organizations, and other educational / non-profit institutions in performing their device processing, E-Beam lithography, material growth, and material and device characterization. Approved qualified processors may utilize this facility directly or obtain direct service help to enable tasks which will further the goals of NASA. The state-of-the-art semiconductor processing facilities and equipment are modified, upgraded and maintained to enable this approved work. An independent staff of semiconductor processing specialists is supported to assist in this work and provide processing assistance, equipment orientations and training, and ensure the appropriate procedures are followed and documentation maintained to ensure the quality and safety of operations for all users. Safety and operational procedures are documented in the Microdevices Laboratory Safety Manual: Operations, Policies and Procedures Plan (JPL D-6226). Access and service charges are defined annually in the "MDL Technical Support Services Holding Account Plan." Interested parties should contact the Process Owner / MDL manager **(James.L.Lamb@jpl.nasa.gov)** for specific details.

Microdevices Laboratory (MDL)

MDL CAPABILITIES

CENTRAL PROCESSING FACILITIES

DEPOSITION OF MATERIALS

- Metal layers
- Dielectric layers
- LPCVD: Si nitride, Si dioxide, polysilicon
- Evaporation, sputtering deposition
- ECR dielectric deposition

LITHOGRAPHY

- Contact and non-contact photolithography
- E-Beam lithography (staff operated)
- CAD system, electronic design input
- Photomask making / inspection / verification

PROCESSING

- Wet chemical etching
- Ion milling, RIE & CAIBE dry etching
- Annealing, diffusion, & oxidation furnaces & RTPs
- Deep Trench RIE (DRIE)
- Si micromachining (Wet, dry, fusion/anodic bonding)
- Wire & die bonding, scribing, dicing
- Flip Chip aligning/ bonding

MEASUREMENT

- Electronic characterization (I-V, C-V, Hall)
- Scanning electron microscopy
- ESCA (staff operated)
- Ellipsometer, profilometer
- Atomic force microscopy
- Transmission electron microscopy w/ EDAX

OTHER TASK SPECIFIC CAPABILITES

DEPOSITION OF MATERIALS

- MBE of III-V & group IV materials
- MOCVD deposition of III-V materials
- Laser ablation of superconductors, etc.
- PECVD of carbon nanotubes

LITHOGRAPHY

- Expertise in high-resolution structures
- Gray-scale lithography

PROCESSING

- Superconductor processing expertise
- Si micromachining expertise
- LIGA processing capability

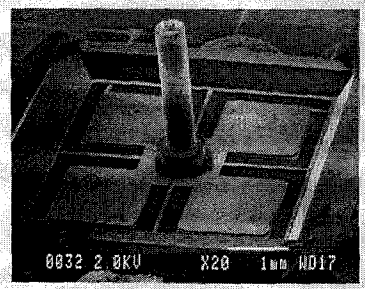
MEASUREMENT

- STM & BEEM
- Optoelectronic characterization
- FTIR, photoluminescence
- X-Ray Diffraction

Technology Development Areas

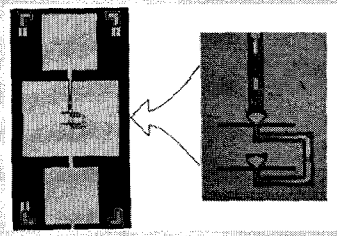
Microdevices Laboratory (MDL)

Microinstruments and MEMS devices

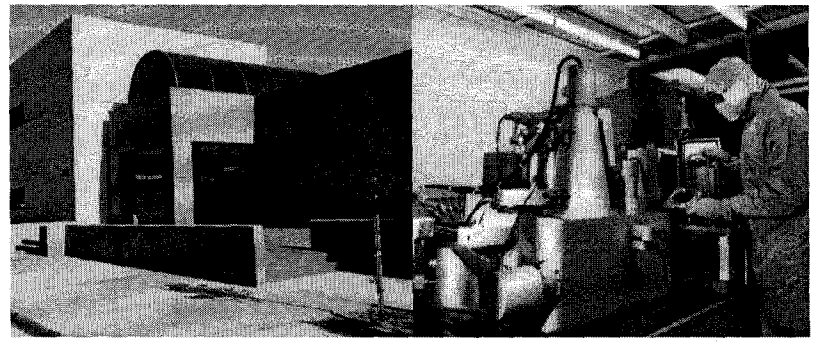


- Surface / Bulk / LIGA micromachining
- Microinstruments including
  - μ-seismometer
  - micro gyroscope
  - micro weather station
  - electronic nose
  - micro propulsion

Superconducting Devices



- Mixer arrays for sub-mm astronomy and atmospheric chemistry
- SIS and hot electron bolometer mixers
- Far infrared bolometers
- Lo-T_c and hi-T_c materials and devices



The Microdevices Laboratory (MDL) is a state-of-the-art, end-to-end device development facility focused on creating and developing new device concepts for space applications -- building blocks enabling NASA's vision of smaller, faster, cheaper spacecraft

MDL Facilities include: Class 10 cleanrooms; E-beam and optical lithography; MBE, MOCVD, PECVD, and LPCVD growth systems; RIE systems; and full processing and characterization capabilities

Specialized semiconductor processing service support is available through the Provide MDL Services Process under the Provide Enabling Services Domain at JPL.
For more information contact: James.L.Lamb@jpl.nasa.gov

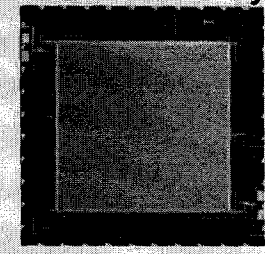
FOCUS METRICS:

- **Inventions**
- **Flight Experiments for Technology Demonstration / Validation**
- **Flight Enabling / Enhancing Microsensors & Instruments**

UTILIZED BY:

- **Universities**
- **Industry**
- **Other Government Agencies**
- **Other NASA Centers**

Infrared & Ultraviolet Focal Plane Arrays



- Quantum well Infrared photodetector (QWIP) arrays based on GaAs/AlGaAs
- Enhanced UV / X-ray CCDs via MBE δ-doping
- Micromachined thermal infrared detector arrays
- GaN growth & devices

Photonic Systems

- Tunable diode lasers for spectroscopy
  - Narrow linewidth
  - Ambient temperature
  - λ out to 2.06 μm
- Laser arrays for high rate communications (10's GB/sec)
- Laser metrology systems for optical & radar interferometers
- Integrated optoelectronics
- Unique diffractive optics

Microdevices Laboratory (MDL)

ACCOMPLISHMENT METRICS

INVENTIONS

- Ballistic Electron Emission Microscopy (BEEM)
  - 1990 R& D 100 Award
- Tunnel Transducer & Tunnel Sensors
  - 1993 R& D 100 Award (Uncooled IR Detector)
- InGaAsP IR Laser at 2.0 μm
- Quantum Well Infrared Photodetector (QWIP) Improvements
  - Coupling Optimizations
  - Broad Band & Multi-Color QWIPS
- Micro Hygrometer
- δ-doped UV / X-Ray CCD

DEMONSTRATION HARDWARE

- First 256x256 LWIR 9 μm hand-held and palm-size QWIP cameras (utilized in numerous studies esp. medical)
- Hand-held UV camera

FLIGHT EXPERIMENTS & DEMONSTRATIONS FOR TECHNOLOGY DEMONSTRATION/ VERIFICATION

- CRRES / RADMON --1990 (Radiation sensors)
- RRELAX RADMON SDIO/NASA Clementine1--1994 (Radiation Sensors)
- VIGILANTE (9 μm QWIPs, UV CCD, APS)--1998-2000
- Kuiper Airborne Observatory, Keck (Submm-Wave Receivers)
- STRV-1D (12 μm 128X128 QWIP);
- STRV-2 (APS, radiation sensors, tunneling accelerometer)
- CAMEX-3 &-4 (Micro Hygrometer, 1995 & 2001)
- AFRL & BMDO's Discriminating Interceptor Tech Program (640X486 8-9 μm and 11-12 μm dual band QWIPs)
- SuZie, MAXIMA, BOOMERANG, BOLOCAM (Spider Bolometers)
- HTSSE 1, NRL --1993 (Hi Tc Superconducting,10GHz low pass microwave filter)
- Martin Marietta AstroSpace -- 1994 (Integrated Charge Monitor)
- X33 Flight Experiment (micro Gyro)
- QWICPIC, Mt. Palomer Observatory (9 μm 256X256 QWIP)
- DoD ISTEF Facility (CTIS) 1998-2000
- HOMER, Mt. Palomer Observatory (UV CCD)
- STS-95 ENose Flight Experiment -- 1998
- JPL Reference Radiosonde, NASA NOAA Balloon flight -- 1998 (Micro Hygrometer)

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ACCOMPLISHMENT METRICS

MISSION ENABLING / ENHANCING MICRO SENSORS & INSTRUMENTS -- PAST

- Mars Oxidant Sensor Head (MOx) (Russian Mars '96)
- Tunable Diode Lasers (TDLs) (Mars 98, MVACS & New Millennium DS2 Mars Probes)
- Communications Board (DS2 Mars Probes, Mars '98)
- SIS & HEBs (SOFIA)
- X-ray collimating grid (HESSI)
- UHFC Microseismometer (RoLand)
- Submm components (EoS/MLS)
- 95 GHz high power transmitter (CloudSat)
- E-Beam gratings (New Millennium EO-1/ HYPERION and Airforce WARFIGHTER--2000)
- AFM, dust imaging & soil analysis (Mars 01/MECA) --canceled after completion, *placed in storage--1998-2000.*
- Delivered 50 LWIR (256x256) focal planes to Boeing --2000.

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ACCOMPLISHMENT METRICS

MISSION ENABLING / ENHANCING MICRO SENSORS & INSTRUMENTS -- PRESENT

- Micromachined, uncooled thermopile IR linear arrays (PMIRR-II instrument, Mars Reconnaissance Orbiter, 2005).
- Superconductor-Insulator-Superconductor (SIS) mixers (band 5 --1120-1250 GHz, HIFI Instrument, Herschel Space Observatory, 2007).
- Hot electron bolometer (HEB) mixers (band 6 --1410 - 1919 GHz, HIFI Instrument, Herschel Space Observatory, 2007).
- Silicon nitride micromesh ("spider web") bolometer arrays (SPIRE instrument, Herschel Space Observatory, 2007).
- UHFC Microseismometer (Baselined French Mars Netlander, 2007)
- HEMTS (Herschel Space Observatory / PLANCK, 2007)
- TDLs -- ABB Bomem (satellite missions through 2003)
- E-Beam gratings (APL, NASA instrument COMPASS, delivery in 2001)
- 13 μm 640X512 high QE QWIP focal plane array (QWIPIC, Palomar 200" telescope--integrating to camera, 2001)
- 10-15.4 μm 640X512 Broad-band QWIP focal plane array (Spatially Modulated Infrared Spectrometer -- testing, 2001)
- Four-color (3-5, 8-9.5, 10-12, and 13-15 μm) 640X512 QWIP FPA (Hyper Spectral Imager, GSFC).

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ACCOMPLISHMENT METRICS

MISSION ENABLING / ENHANCING MICRO SENSORS & INSTRUMENTS -- FUTURE POTENTIAL

- A negative Fresnel lens fabricated as the correlator element for a large aperture, deployable, Fresnel telescope (DRDF project with LLNL)
- SIS and HEB mixers for the Advance Microwave Limb Sounder instrument, 2009.
- Micromachined Uncooled thermopile IR Detectors and arrays (Europa Orbiter mission, PIRE instrument for Pluto POSSE mission)
- Mars Organic Detector (MOD) for fundamental biology and bound water detection, candidate for Mars 2005 or 2007.

- Dual broad-band QWIP FPAs (6-10, 10-15 μm) for miniature imaging interferometer.
- Large format NIR (0.9-2.0 μm) FPAs.
- Sb-based materials growth allowing improved instruments (some with orders of magnitude improved sensitivity)and enabling technologies in
  - Mid-IR (2-9 μm) infrared lasers;
  - Long-wavelength infrared detectors;
  - Thermo-photovoltaic devices;
  - Millimeter wave imagers

  for LIDAR; Earth and planetary remote sensing; In-Situ sensing; Life detection; Bio astronautics; Astronomy; Weather monitoring; Pollution monitoring; and Power sources.
- Group III-nitride focal plane arrays for solar-blind UV
- Silicon UV imaging arrays for UV and low energy particle detection (promising instrumentation for life detection)
- Curved focal plane arrays for improved performance
- Nanostructure-based quantum devices for nonvolatile memory and Wavelength Detector Arrays
- Vibratory Micro-gyroscope providing low power, low volume, low mass capability for avionics and positioning.

ACCOMPLISHMENT METRICS

MISSION ENABLING / ENHANCING MICRO SENSORS & INSTRUMENTS -- FUTURE POTENTIAL (Con't)

- MEMS-based micro-instruments promising increased sensitivity and reduced size and volume requirements:
  - Mars Environemtal Compatibility Assessment (MECA) flight instrument reprise (with wet chemistry cells, electrometer, optical/AFM microscopy, patch plates, abrasion testing)
  - Atmospheric Electron X-ray Spectrometer (AEXS)
  - Force Detected Nuclear Magnetic Resonance (FDNMR) Spectrometer
  - In-situ Spectrometers for Geo-chronology utilizing LIDAR and Pulsed Fiber laser.
  - Miniature Local Electrode Atom Probe (Mini-LEAP) offering 3-D compositional imaging
  - Chemical Atomic Force Microscope (AFM)
  - LIGA based Quadrupole Mass Filter offering the potential of order of magnitude reduction in size of Quadrupole Mass Spectrometers
  - Microweather station (micro-hygrometer, and Micro-optical wind and dust sensors)
  - Multisensor E-tongue/Water quality monitor
  - Mars Oxidation Instruments (MOI, MAOS) -- (was a candidate for BEAGLE II in '03);
  - Fluid velocity sensor (joint with CIT0 with applications to wind tunnels and the Aerospace industry

- Numerous development activities with potential instrument and flight pay-offs:
  - Vaporizing Liquid Microthruster (VLM); Field Emission Electric Propulsion; Free Molecule Micro Resistive jet (FMMR); Micro-Inductors; MEMS Magnetometer; LIGA-based Scroll Pump; MEMS Micro-Isolation Valve; MEMS piezoelectrically -actuated valve; MEMS-based thermal transpiration (Knudsen) Pump; Adaptive Optics; MEMS-based incandescent sources for illumination, calibration, and gas-sensing; Microfludics / in-situ chemistry systems including microfluidic ion chromatograph; Cryobot and sensor web development;

- Nanotechnology-based senors, devices, and instruments based on arrayed carbon nanotubes, etc. offering potential
  - Biomolecular analysis
  - Biomimetic acoustic sensors
  - High-Q nano-oscillators for mechanical signal processing and chemical sensors

ACCOMPLISHMENT METRICS (Con't)
EXAMPLES OF RAPID PROTOTYPING

(LESS THAN 2 YEARS FROM CONCEPT TO HARDWARE DEMONSTRATION)

- **UV CCD INCORPORATING MBE-DEPOSITED DELTA-DOPING LAYER**
- **TUNNELING IR SENSOR (MICRO GOLAY CELL)**
- **UHFC MICRO SEISMOMETER**
- **TUNNELING MICRO ACCELEROMETER/HYDROPHONE**
- **MICROMACHINED HUMIDITY SENSORS**
- **VIBRATORY MICROGYROSCOPE**
- **COMPUTED TOMOGRAPHY IMAGING SPECTROMETER**

Microdevices Laboratory (MDL)

Past Examples of Services Provided

- ULTRA-CLEAN, ESD-FREE MICRODICING:
  - CCDS (CASSINI, MISR, STARTRACKER, CSULA, ACE, CHEX, etc.)
  - Custom VLSI chips (CRIS, SIS, and ULEIS)
- DIFFRACTIVE OPTICS DESIGNS AND FABRICATIONS (EO-1)
- SUB-MICRON PATTERNINGS OVER LARGE AREAS
- XPS (SURFACE) ANALYSES & TEM
- INDIUM BUMP BONDING AND FLIP CHIP BONDING (HEFT, APS)
- THIN FILM EVAPORATIONS
- ELLIPSOMETER AND STRESS ANALYSES
- SPECIALIZED MEMS FABRICATIONS & DEPOSITIONS (MARS '96 -- MOx; GENESIS; GALEX)
- CLEANROOM DESIGN EXPERTISE (MECA; Mars '03--ISIL; MSR)
- NUMEROUS DIRECT TASK COLLABORATIONS

Microdevices Laboratory (MDL)

SUMMARY

MDL OFFERS UNIQUE CAPABILITES AVAILABLE TO THE JPL COMMUNITY

ONLY FACILITY THAT COMBINES:

- **WORLD-CLASS STAFF & DEVICE PROCESSING EQUIPMENT**
- **LEVERAGED FUNDING & INVOLVEMENT FROM NASA, DOD, AND INDUSTRY**
- **END-TO-END FABRICATION CAPABILITY FOR RAPID PROTOTYPING**
- **FOCUS ON MICRODEVICES FOR SPACE APPLICATIONS**
- **CENTRAL ORGANIZATION TO ENABLE ACCESS BY OUTSIDE USERS**

SUMMARY OF RESEARCH AND DEVELOPMENT AREAS:

- **MICROINSTRUMENTS AND MEMS DEVICES**
- **DIODE LASERS & INTEGRATED PHOTONIC SYSTEMS**
- **DIFFRACTIVE OPTICS**
- **INFRARED & ULTRAVIOLET FOCAL PLANE ARRAYS**
- **HIGH SPEED DEVICES & THz SOURCES**
- **NANOTECHNOLOGY & DEVICE DIAGNOSTICS**

ACCESS TO MDL AND MDL SERVICES IS INITIATED BY CONTACTING THE MDL MANAGER, JAMES L. LAMB (@4-5019 or James.L.Lamb@jpl.nasa.gov)